Picosecond Laser Krypton Plasma Emission in Water-Window Spectral Range

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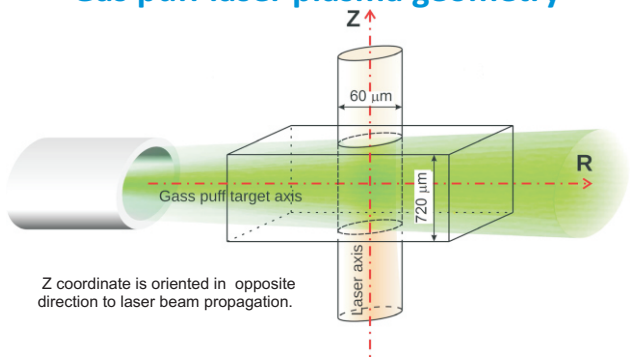
Introduction

Laser plasma created in krypton gas puff target is studied as a source of radiation in the water window spectral range. Spatial development of plasma induced by Nd:YAG laser pulse (170 ps/480 mJ) with peak power density 10^{14} W cm^{-2}, incident on the gas-puff target is modeled using 2D RMHD code Z* [1].

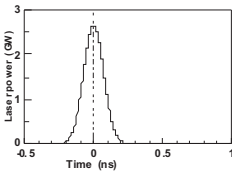
Gas puff laser plasma geometry



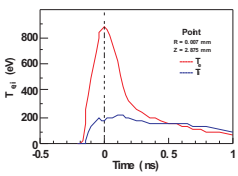
Time dependences

The time dependences of plasma electron temperature and electron density in represeative points are introduced into the kinetic code FLYCHK [2].

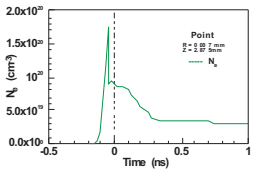
Laser power



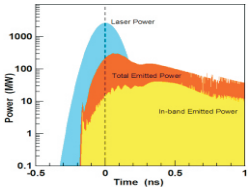
Electron and ion teperatures



Electron density



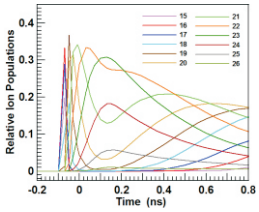
Plasma emission



Radiation in wide spectral region is emitted for a long period after the laser pulse.

Highly ionized Kr atoms are responsible for line spectral components in SXR region.

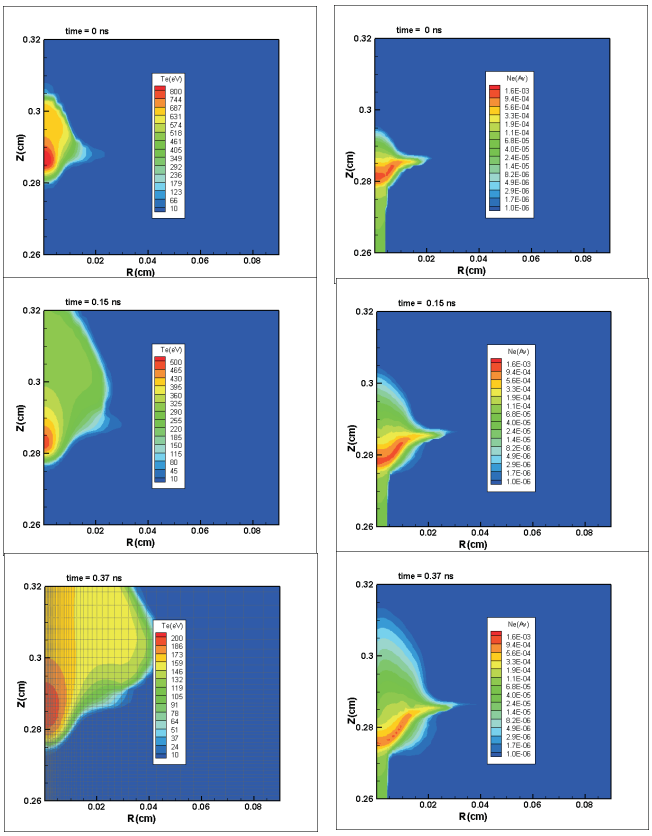
Ion abundances



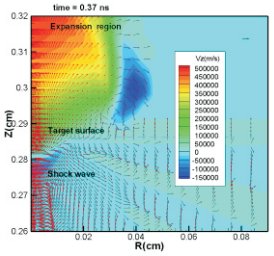
Spatial evolution of plasma

Electron temperature

Electron density



Plasma movement



Generated plasma expands very quickly opposite to the laser beam. In the direction of the beam a compression wave is created. The beam propagation is stopped when the critical value of electron density is reached.

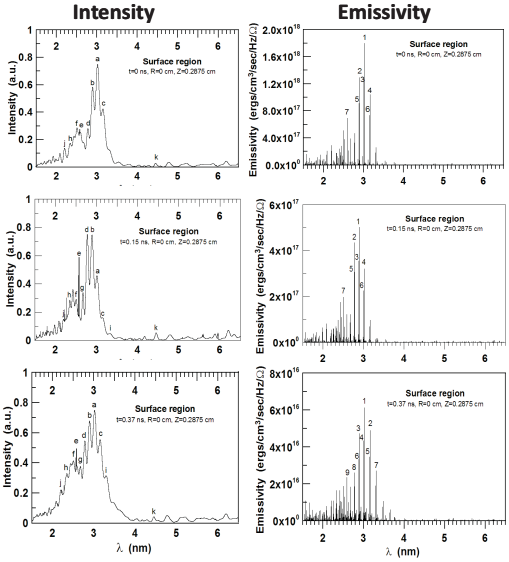
Instantaneous plasma velocities at time delay 370 ps after the laser peak illustrate that the plasma without moving is found in the region of the critical density .

Instantaneous spectra estimation

Intensity

Emissivity

Transitions



Label	ISO	Transition	Wavelength nm	Emissivity erg/cm³/s/Hz/Ω
0 ns		R=0.007 cm	Z=2.875 cm	Central
1	15	3d² - 4f²	3.02260	1.8e+18
2	14	3d² - 4f²	2.89743	1.3e+18
3	15	3d² - 4f²	3.00789	1.3e+18
4	16	3d² - 4f²	3.16025	1.0e+18
5	14	3d - 4f	2.88389	9.1e+17
6	16	3d - 4f	3.14419	7.4e+17
7	15	3p⁵ - 4d²	2.58913	6.9e+17

Label	ISO	Transition	Wavelength nm	Emissivity erg/cm³/s/Hz/Ω
0.15 ns		R=0.007 cm	Z=2.875 cm	Central
1	14	3d² - 4f²	2.89743	5.0e+17
2	13	3d² - 4f²	2.78205	4.3e+17
3	14	3d - 4f	2.88389	3.5e+17
4	15	3d² - 4f²	3.02260	3.2e+17
5	13	3d - 4f	2.76954	3.1e+17
6	15	3d - 4f	3.00789	2.3e+17

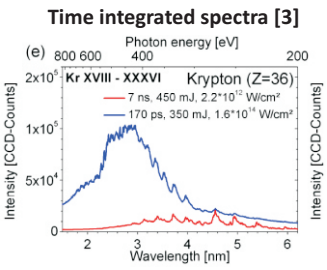
Label	ISO	Transition	Wavelength nm	Emissivity erg/cm³/s/Hz/Ω
0.37 ns		R=0.007 cm	Z=2.875 cm	Central
1	15	3d² - 4f²	3.02260	6.1e+16
2	16	3d² - 4f²	3.16025	4.9e+16
3	14	3d² - 4f²	2.89743	4.7e+16
4	15	3d - 4f	3.00789	4.3e+16
5	16	3d - 4f	3.14419	3.5e+16
6	14	3d - 4f	2.88389	3.3e+16
7	17	3d² - 4f²	3.31074	2.7e+16
8	13	3d² - 4f²	2.78205	2.6e+16
9	15	3p⁵ - 4d²	2.58913	2.4e+16

Conclusion

Our computer model of laser plasma indicates that the spectrum of emitted radiation is changing very fast, not only during the laser pulse, but also over a long period after the pulse.

Time integrated spectra in the spectral range 2 – 6 nm [3] measured under the same conditions as those used for modeling are adequate. The highest emissivities correspond to quantum transitions of ions Kr^{+20}, Kr^{+21}, Kr^{+22} and Kr^{+23}. The krypton laser plasma at ~ 150 eV may be also considered as a possible candidates for source of water window radiation [4].

Time integrated spectra [3]



References

[1] S.V. Zakharov et al., in EUV Source for Lithography, SPIE Press 2005, p. 223.
[2] H.-K. Chung, et al., High Energy Density Physics, Vol. 1, p.3 (2005).
[3] M. Muller, et al., Optics Express, 2013, 21(10) DOI: 10.1364/oe.21.012831.
[4] V.S. Zakharov, Proc. 2013, Int. Workshop on EUV and SXR Sources, Dublin, Ireland.

Acknowledgments

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